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PHYSIOLOGICAL ACCEPTABILITY TESTS OF THE SJU-5/A EJECTION SEAT --ETC(U)
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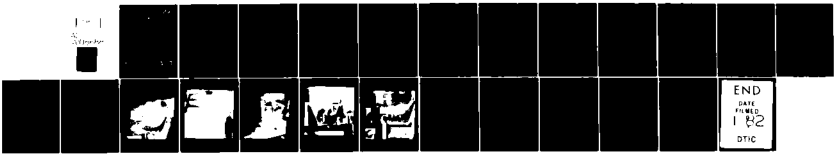

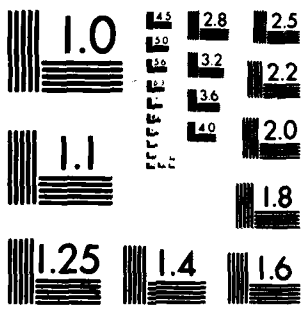

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REPORT NO. NADC-81215-60

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LEVEL III

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PHYSIOLOGICAL ACCEPTABILITY TESTS OF THE SJU-5/A EJECTION SEAT

SECOND PHYSIOLOGICAL ACCEPTANCE DEMONSTRATION

William Ward Jr. and Kenneth Miller
Aircraft and Crew Systems Technology Directorate
NAVAL AIR DEVELOPMENT CENTER
Warminster, Pennsylvania 18974

1 JULY 1981

FINAL REPORT
AIRTASK NO. W06250000
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Prepared for
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Washington, D. C. 20361

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This program was conducted to evaluate solutions to deficiencies of the F18 Aircraft Martin-Baker SJU-5/A escape system which had been identified during conduct of the initial Physiological Acceptability Demonstration (Report No. NADC-79040-60). The proposed solutions evaluated during this program included: incorporation of "toe guides" on the rudder pedals, relocation of the head rest, modification of the back support, and incorporation of leg garters into the anti-"G" suit. Of these, the head rest and back support still require additional modification. Upon satisfactory correction of the head rest and

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back support deficiencies, physiological acceptance of the F18 escape system will be recommended for the pilot's station.

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INTRODUCTION

The F/TF-18 aircraft manufactured by McDonnell-Douglas Aircraft Corporation (MDC) incorporates a new Aircrew Automated Escape System (AAES), the Martin-Baker Aircraft Co. (MBA) ejection seat (SJU-5/A). The Naval Air Development Center (NADC) has been conducting Physiological Acceptance Demonstration tests on this AAES as required by MIL-E-9426 and completed initial testing on October 1978.[1] During these tests several discrepancies were identified which could affect ejection safety, of which the most significant were: ejectee foot-leg contact with instrument panel, lower back injuries, excessive head rotation and leg garter slippage from the mid-calf position. Physiological acceptance was not recommended,[2] pending correction of these deficiencies and evaluation on the NADC ejection tower. MDC redesigned components to solve the first three deficiencies, the NADC designed a "G" suit-garter combination to solve the fourth. A second Physiological Acceptance (Δ P.A.D.) was undertaken in October 1979, incorporating the redesigned components, and was completed in January 1980. Physiological Acceptance of the F18 ejection seat was withheld[3] pending correction of minor deficiencies still existing in the headrest and back support.

Forty-one (41) ejection tests were conducted on the NADC ejection tower. Of these, six were conducted with dummies and thirty-five were conducted with seven volunteer subjects as seat occupants. Significant differences existed between the "toe guide" rudder pedal configuration used for this Δ P.A.D. and the rudder pedal configuration submitted by MDC for the initial P.A.D. This difference precluded a direct comparison of lower leg trajectory between the latter and former tests. The final three tests of this series were conducted with the "toe guide" installed on one side and only the rudder pedal on the other side, using selected subjects who had contacted the toe guides in previous tests. The NAMC 40-inch stroke steel test catapult was used because it adequately replicates the initial acceleration signature of the Martin-Baker service catapult in the area of concern. See figure 1.

SUMMARY OF RESULTS

The toe guide submitted by MDC, (figure 2), changed the trajectory of the lower legs and moved the instrument panel contact towards the toe.

A modified head rest provided by MDC significantly reduced head rotation except for the larger seated height subjects. A protrusion at the top center of the head rest placed there to provide clearance for hardware prevented the helmet and head of the larger subjects from moving aft to a better ejection posture.

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1. Report No. NADC-79040-60, Physiological Acceptability Tests for SJU-5/A Ejection Seat, 1 February 1979.
2. Commander NAVAIRDEVCEN letter 6034 S/N 7279 dated 22 September 1978.
3. Commander NASC letter 5312G T.A.P. Ser #162 APR 22 1980.

The back support shell supplied by MDC was considered unacceptable for live subject tests since it was still too flexible in the lumbar area and still had the potential of causing possible scapular injury. The back support which had been modified by NADC and used in the first P.A.D. was therefore used for human subjects on these tests.

The "G" suit/leg garter combination eliminated the original complaint of slippage and misalignment[1]. The effectiveness of leg restraint varied from adequate to good, depending on fit and adjustment. Additional testing has been accomplished by the Naval Air Test Center and is described in their report.[4]

CONCLUSIONS

1. Feet to instrument panel contact with the toe guides installed represents a significant improvement over the baseline configuration.

2. The modified head rest significantly reduced head rotation over the baseline configuration except for the larger (seated height) subjects.

3. The modified back support is unacceptable for human subject use.

4. The "G" suit/leg garter combination is adequate for the F/A-18 crew station.

RECOMMENDATIONS

1. The current toe-guide design should be considered acceptable. However, the effectiveness of the toe guide can be increased by lengthening the guide and/or increasing resistance to flexure. These options should be investigated.

2. The head rest should be considered acceptable after the protrusion is removed from the top center.

3. The back support should be considered unacceptable until modified to provide lumbar support and reduce scapular impingement.

4. The "G" suite/leg garter combination should be considered acceptable.

TEST SET-UP DESCRIPTION

All tests described herein were conducted on the NAVAIRDEVCEN ejection seat tower facility. The ejection seat tower is a 150 ft structure inclined and supported at an angle of 20 degrees, 50 minutes from the vertical. Being

4. Naval Air Test Center Report SY16R-80 4/25/80

man-rated, it is an important tool in determining the physiological acceptability of the catapult escape system acceleration forces on the human volunteer subjects being used for assessment.

TEST EQUIPMENT

The following describes the major components used in conducting the tests described in this report:

1. Ejection Seat

The SJU-5/A ejection seat MBEU 65101, issue A, S/N HTT-0001. All unnecessary components were removed from the seat to minimize total ejected weight (TEW) on the tower. A special firing mechanism cable was fabricated to adapt the seat firing control to the tower catapult. Strain gages were installed at critical stress locations on the seat bucket sides to monitor potential failure points. NOTE: Components removed from the seat were not pertinent to the test results.

2. Survival Kit

The SKU-3/A Rigid Seat Survival Kit (RSSK) East-West Industries, Inc. (EWI) P/N 253J100-1 S/N 009, outside configuration only. Seat Cushion EWI P/N 39041-253J670-1.

3. Back Support

The back support (MBEU 66939-1 155.B) submitted for this evaluation was still considered unsuitable for human subject use. Therefore, the back support modified with a lumbar stiffener and scapular support was sued for this series of tests.

4. Head Rest

The modified head rest shell submitted for this evaluation improved head location for all but the large subject. The headrest shell was removed for tests involving the large subject.

5. Torso Harnesses

The torso harnesses were a standard or cut-away version of the MA-2.

6. Anti "G" Suit

Four anti-"G" suits (MARK 2A) were supplied by NATC, Patuxent River, to incorporate a single leg garter for leg restraint. Of the four units supplied, one had the garters sewn to the anti "G" suit. The other three had provisions for reeving in the garters. See figure 3.

7. Communication System(s)

Helmet APH-6 single and dual visor with oxygen mask A-13/A. Three sets of helmet/mask combinations were electrically modified to permit direct communication

between the human subject, the Medical Officer, and the test director(s). The resultant configuration was equivalent to the in-service configuration, figure 4.

8. Aircrew Station Mockup (Pilot)

A simulated cockpit floor was installed at the base of the tower, upon which were mounted the rudder pedal/toe guide installations supplied by MDC. Also attached to the floor were the center pedestal mock-up and leg line floor brackets. Two pieces of clear plastic were used to represent limitations of the side panels in the foot well. A styrefoam panel was installed for each test to simulate the instrument panel edge. The entire aircrew station was installed precisely in accordance with specifications and drawings supplied by MDC. The installation was checked by use of templates supplied by MDC. Periodic checks were made during the progress of the program. See figures 5 and 6.

INSTRUMENTATION DATA TECHNIQUES

Table I lists the data recorded for each test. All instrumentation was calibrated in accordance with standard procedures.

Analog signals were recorded on a direct writing Honeywell Model 1912 oscillograph for "quick-look" analysis, and parallel recorded on an Ampex Model 1300 magnetic tape recorder to permit a more detailed data analysis subsequent to the test, as well as being a backup in case of an oscillograph failure. Figure 1 shows digitized sample curves from a prior test program.

Strain gages were used to record the strains at several points on the seat bucket. The results were monitored to be sure the seat wasn't approaching a yielding load because of repeated testing with human subjects.

The simulated rudder pedals were strain gaged on the transverse bar which supported the sole of the boot to determine the force applied to the rudder pedals by the ejectee. This was not an accurate representation of total force applied since the heel and toe also could be used to apply pressure to the rudder pedal. However, the results supplied a base line approximation of lower leg interaction prior to onset.

PHOTOGRAPHIC DATA TECHNIQUES

Table II lists the photographic equipment and their placement for the series of tests. These cameras were used to observe subject body motion during the test. Camera 3, 4, and 5 were used to obtain detailed foot motion during the test.

TEST SUBJECTS

A series of six dummy ejections at in-service accelerations was conducted to determine toe guide interaction with the dummy's feet, and to verify replication of prior test results. The instrumented kick plate was used for all six tests. Toe guides were installed for three of the six tests. The occupant for a[illegible] six tes[illegible] was a ninety-fifth percentile anthropomorphic dummy, Alderson C.G. m[illegible] S/[illegible]79, weighing 235 pounds. A rate gyro was bolted to the lower right

leg in the region of the knee joint.

Human Volunteer:

			Boarding Weight
1.	Subject B	Miller	157 lb to 158 lb
2.	Subject C	Overstreet	179 lb to 189 lb
3.	Subject D	Johanson	185 lb to 187 lb
4.	Subject E	Murray	178 lb to 183 lb
5.	Subject G	Dears	240 lb to 245 lb
6.	Subject H	Pickard	182 lb to 187 lb
7.	Subject I	Rice	151 lb to 153 lb

Appropriate subject data for each subject is listed in table III. Rudder pedal and bucket adjustment data is included in table IV, Test Matrix.

MEDICAL SUPPORT

For any test program conducted by the Navy which involves the exposure of human subjects, stringent regulations must be followed to insure maximum safety for the subject. For this program a medical support team was on site before, during and after each human subject test. The team was headed by a Medical Officer and included as a minimum, a senior corpsman and two rated corpsmen. In addition, a ready ambulance was on site for each test, plus a portable defibrillator and other emergency medical supplies. Each subject was monitored for EKG response before, during, and after each test, and had direct communications with the Medical Officer and the test directors for an immediate report of physical condition.

D I S C U S S I O N

BACKGROUND

During the initial physiological evaluation of the SJU-5/A, reference 1, the following potential problems were noted: (1) foot and lower leg contact with the frangible instrument panel simulation; (2) lower back injuries, (3) excessive head rotation with related neck muscle strains, and (4) leg garter slippage from the mid-calf position. Although a precise injury assessment could not be made, the potential for injury was considered great enough to defer acceptance of the system.

Items (1), (2) and (3) above were taken for corrective action by MDC. The Navy was to provide corrective design for item (4).

TEST PROGRAM RATIONALE

All necessary improvements, modifications and design changes were to be incorporated into the jection tower test set-up and evaluated using human subjects. NAVAIRDEVCEN ltr 6032 ser 8323 of 30 Oct 1979 contains the final test schedule. Six firings were planned using a 95 percentile dummy, three firings each with toe guides and without toe guides. The rationale was to determine first, if the dummy response (without the toe guides) was similar to that obtained in reference 1, and second, to determine the effect, if any, of the toe guides on the dummy lower leg trajectory.

Concerning human subject occupancy, it was planned to repeat the acceleration profiles using the same subjects, but with toe guides installed. This presumeably would lead to a direct comparison of the dynamic response of the lower leg with and without the toe guides, and therefore permit an a-curate assessment of toe guide efficacy.

TEST CONDITIONS AND RESULTS

The ejection seat used in this program was the same as used in reference 1, the Martin-Baker SJU-5/A. Strain in critical structural areas was again monitored throughout the program. Leg restraint line brackets were installed per MBEU 65000 (K rev.) and load links were installed in-line as in reference 1. The back support received for the program (MBEU 66939-1 1SS.B) was considered unsuitable for live subject use, as it provided no further scapular support and was still too flexible in the lumbar spine area. Back support MBEU 66939-1 1SS A, modified for use during reference 1 was installed.

The modified head rest shell was used up to test No. 33, but had to be removed for subject G to attain a good head position. It was omitted for the balance of tests.

Four pair of rudder pedal supports were received, and installation was made in accordance with MDC DWG 74T043238. The round wooden bars, replicating the toe brake hinge, were strain-gaged to determine the amount of "push-off" force exerted by each subject. Ninety-six toe-guides were received, and a new set was installed to the rudder pedal supports for each test.

The pilot's crew station mock-up was fabricated and installed in accordance with MDC drawings and instructions, and periodically checked with MDC templates. Relationships of the seat to front cockpit critical points (rudder pedals, instrument panel, side consoles) were maintained to an accuracy of ± one sixteenth inch, and ± zero degrees, five minutes.

The Naval Air Test Center (SY71) Patuxent River, Maryland, delivered four (one of each size) modified Anti-G coveralls, MARK-2A, for use on the program. The modification consisted of a tunnel sewn into each leg for placement of the leg garter. One coverall had the leg garters stitched in place.

Test subjects B, C, D, and E had participated in the initial test program. Subjects G, H, and I were new volunteers, with subject G closely representative of the 98th percentile anthropometry. The ejection acceleration build-up was started at a low G level, since the effect of the toe-guides on the lower leg and pelvis was an unknown. As confidence was increased, program testing was accelerated. Initially, the motion film was used for "quick look" reference to monitor subject reaction and safety. A closer analysis later in the program revealed a significant change in initial position of the lower leg as compared to reference 1. Further investigation revealed a significant difference in the configuration of the two rudder pedal mock-ups. A direct comparison between the two series of tests as described in the rationale was not possible. It was therefore decided to conduct additional tests with one toe guide installed, one removed, to get an assessment of toe guide efficacy. For these tests (#01, 02, 03) selected subjects who had previously contacted the toe guide were used. It is concluded, on the basis of these tests, that the toe guide will move the point of instrument panel contact toward the toe, but probably would not eliminate contact completely for all cases.

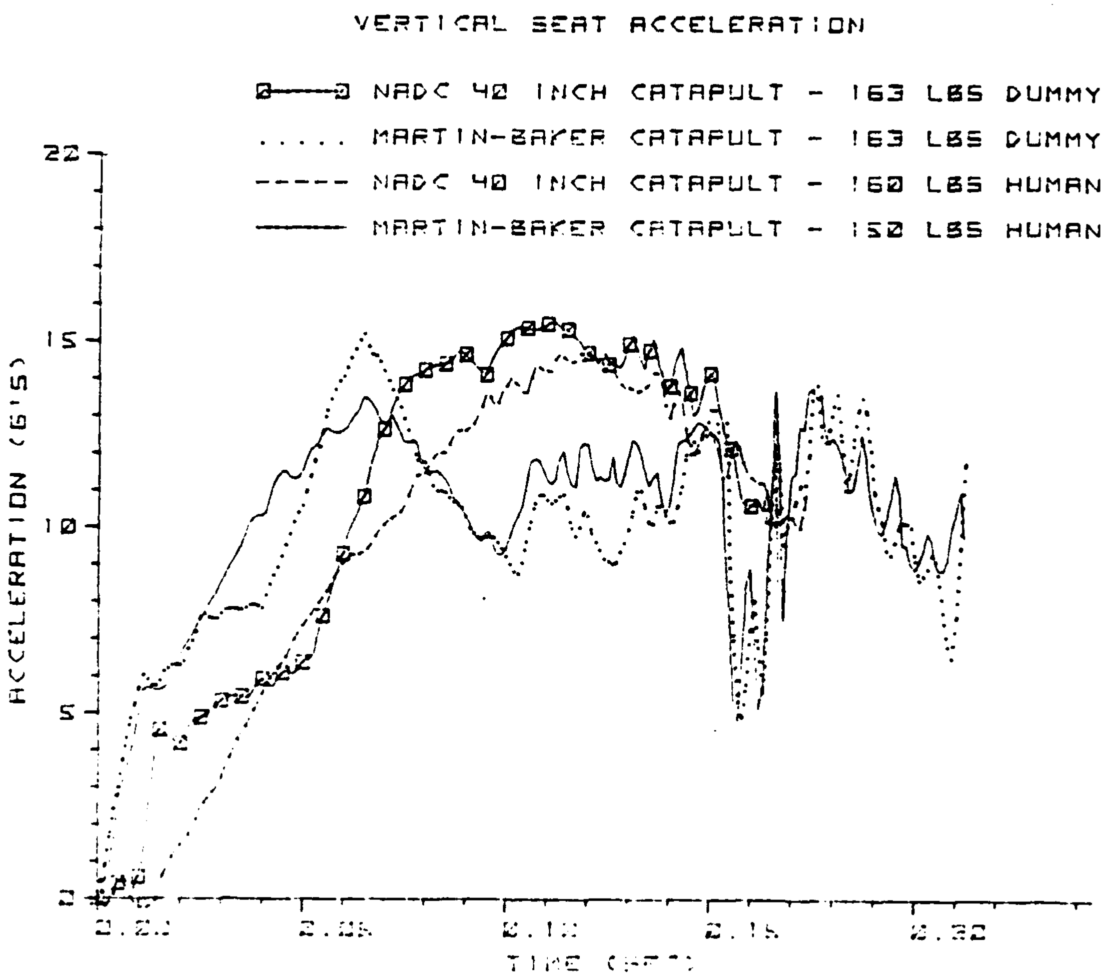

Figure 1 - Typical Acceleration Signatures

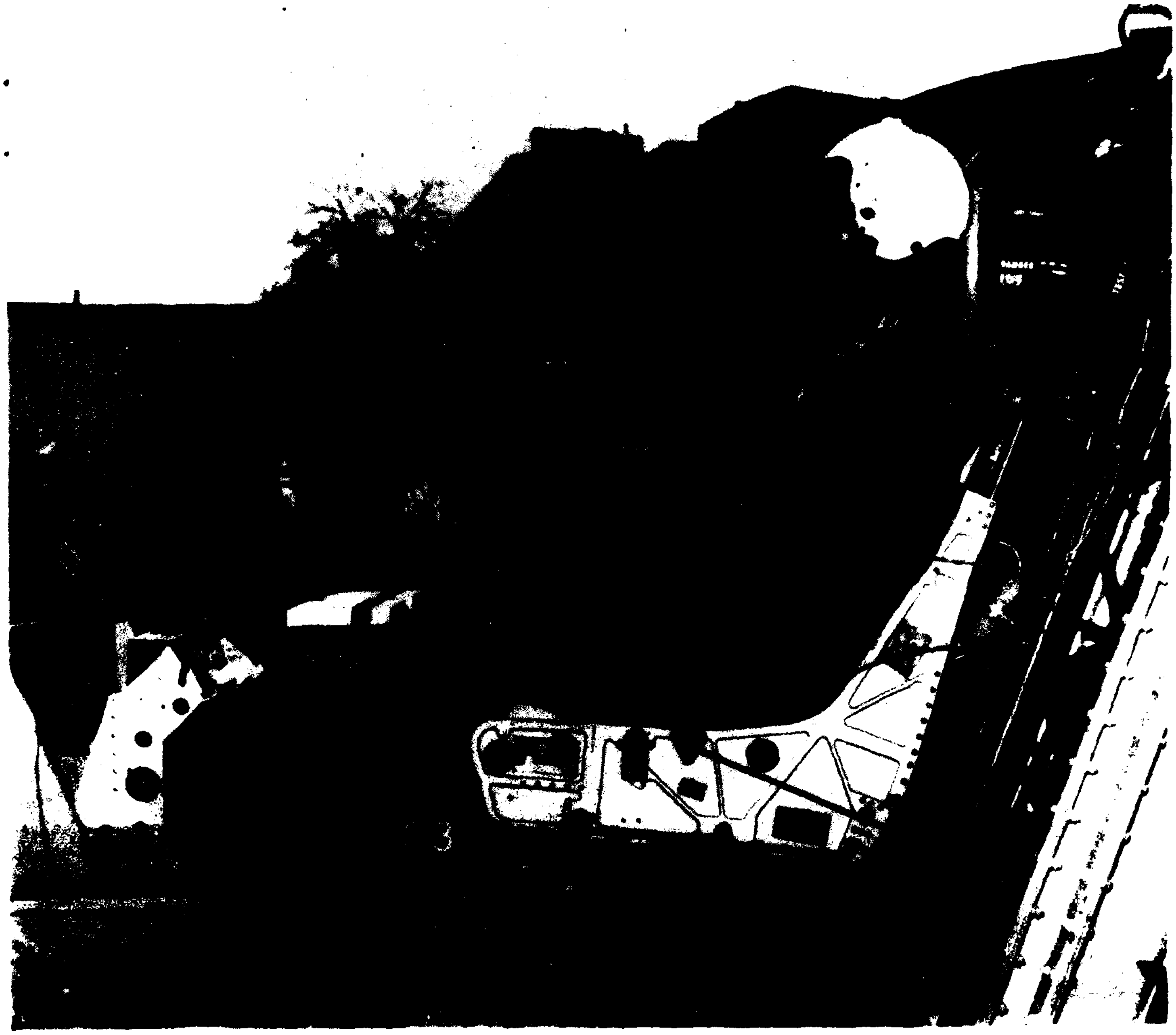

Figure 2 - Toe Guide Installation

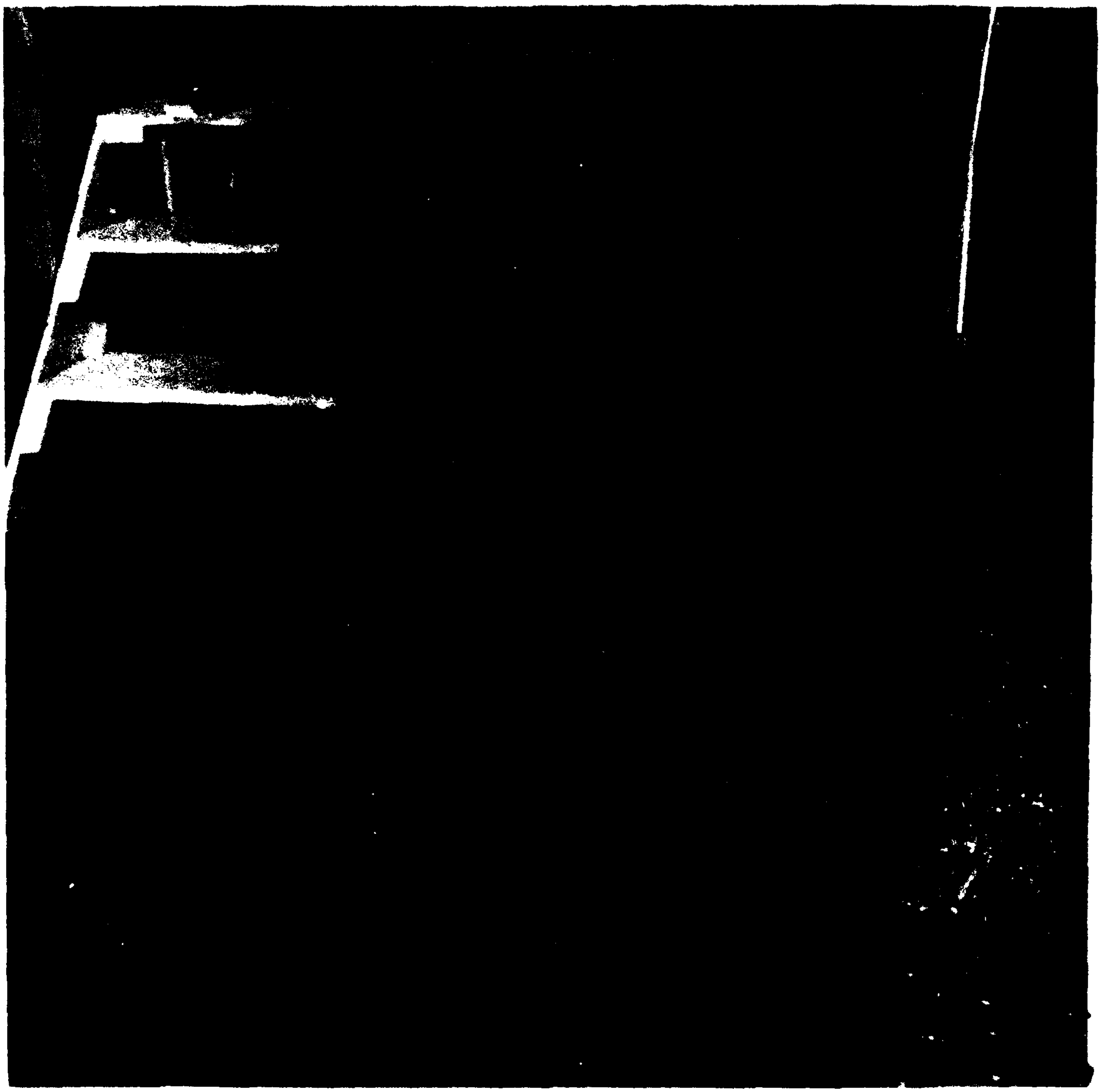

Figure 3 - Anti-"G" Suit/Leg Garter (Rear)

Figure 4 - Communications Checkout

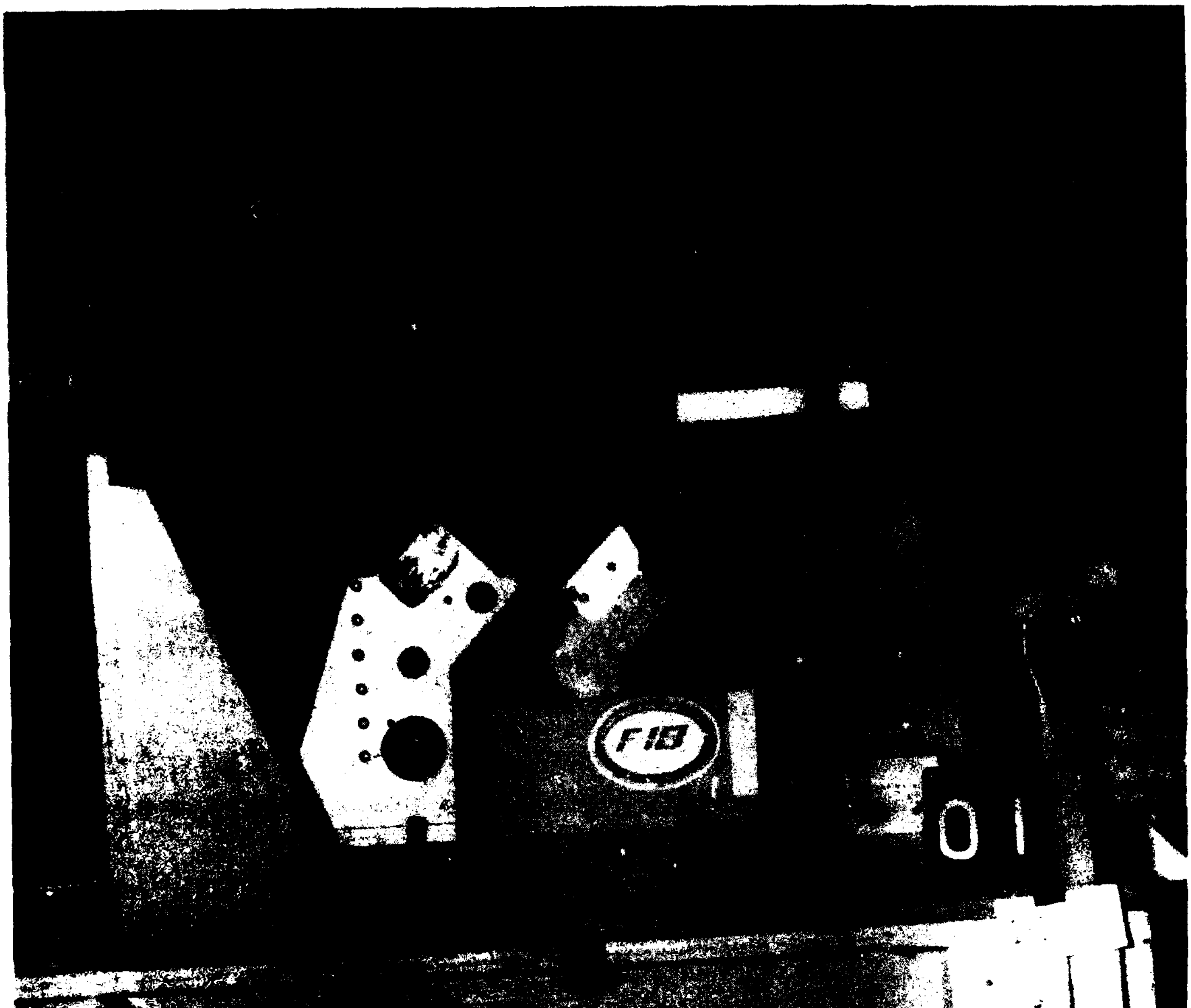

Figure 5 - Aircrew Station Template Check

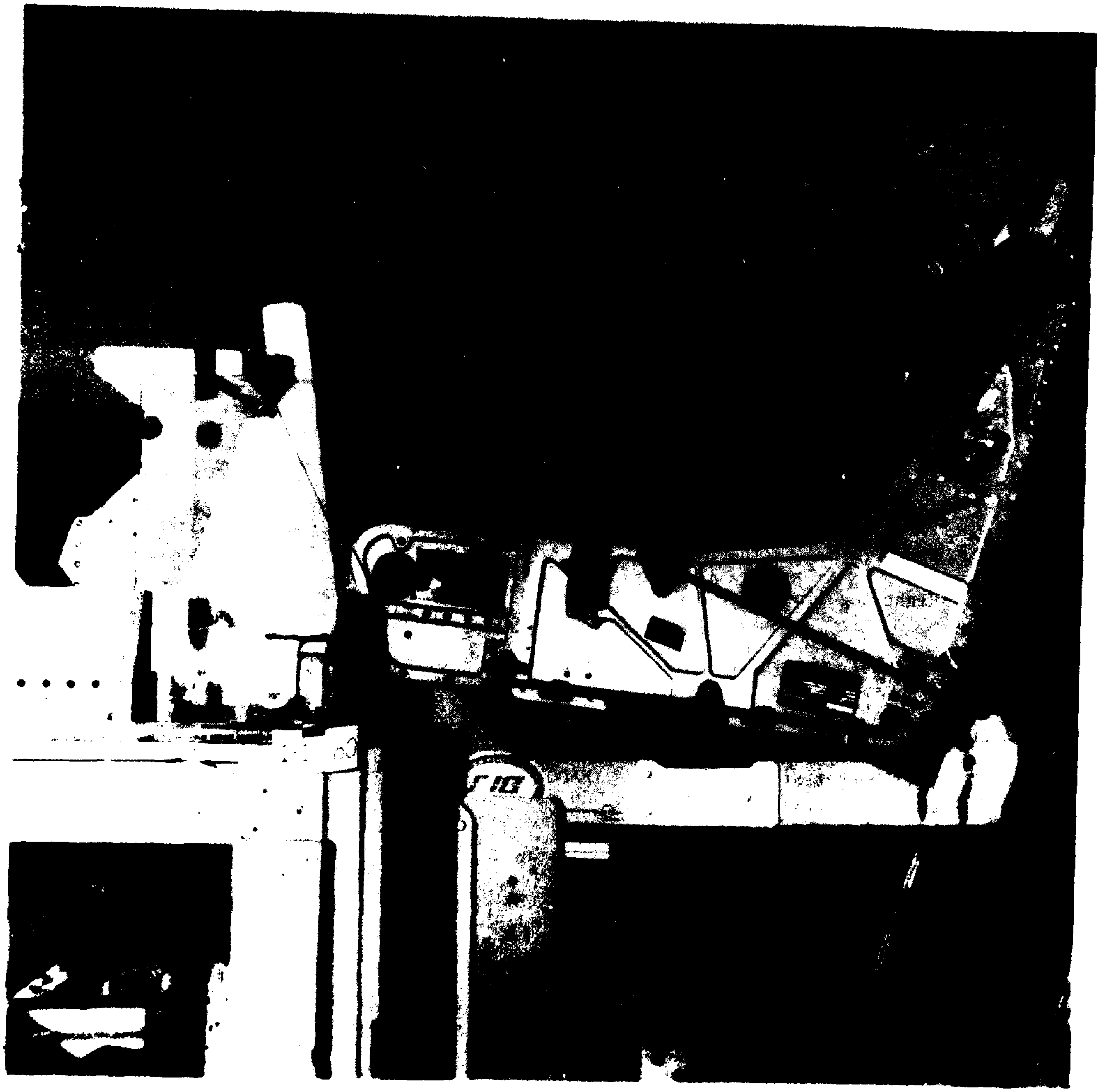

Figure 6 - Aircrew Station Template Check

TABLE I - INSTRUMENTATION DATA CHANNELS

		Manufacturer	Model	Range
1.	Catapult pressure	CEC	4-326-0008	0-2500 psi
2.	Vert. (40" catapult)	CEC	4-202-0001	50± G
3.	Vert. Seat acc.	CEC	4-202-0001	50± G
4.	Horz. seat acc.	CEC	4-202-0001	50± G
5.	Vert. dummy acc.	CEC	4-202-0001	50± G
6.	Horz. dummy acc.	CEC	4-202-0001	50± G
7.	Rate Gyro (dummy right knee)	HUMPHREY	RG28-2571-1	1500± cycle/sec
8.	Kick plate, instrumented	MC AIR	N/A	N/A
9.	Right leg line force	NADC	Strain Gaged link	350 ohm Wheatstone bridge
10.	Left leg line force	NADC	Strain Gaged link	350 ohm Wheatstone bridge
11.	Strobe light sync.	NADC	N/A	N/A
12.	Four bucket strain gages	NADC	N/A	0-5000 lb 350 ohm Wheatstone bridge
13.	Displacement	NADC	N/A	N/A
14.	Rudder Pedal force	NADC	N/A	0-200 lb

TABLE II - PHOTOGRAPHIC COVERAGE

Camera Type	F.P.S.	Coverage
1. Milliken	400	20 deg. right front of seat tracking up rails.
2. HYCAM	1000	Right side of seat covering 0-10 ft up rails.
3. Milliken	400	Right side of seat covering detailed foot motion.
4. Milliken	400	Left side of seat covering detailed foot motion.
5. HYCAM	1000	Left side of console covering detailed foot motion.
6. Milliken	400	Front of seat covering 0-10 ft up rails.
7. Milliken	400	Right side covering

TABLE III - SUBJECT DATA

Subject	Shoe Size	Knee Ht. Sitting (16) (1	Butt-Knee Length (19) (1	Popliteal Ht. Sitting (17) (1	Buttock-Popliteal Length (18) (1
B	9	10	2	3	3
C	8-1/2	40	45	40	55
D	10	35	40	15	30
E	9	25	30	15	10
G	12	90	98	--	--
H	8	20	20	3	30
I	9	65	30	75	30

(1 Visual indices and percentiles in accordance with Acel #533 to the closest line item number reference

NOTE: Integrated anti-G suit/garter in accordance with Naval Air Test Center, Report #SY-16R-80 of 25 April 1980. Each subject was individually fitted with anti-G suit prior to test

TABLE IV - TEST MATRIX

TEST NO.	DATE	SUBJECT	BOARDING WT #	KNEE HT(1) SITTING	BUTT KNEE(1) LENGTH	SHOE SIZE	SEAT ADJUST-MENT(2)	RUDDER ADJUST-MENT(3)	CATA-PULT "G"(4)	G/SEC	TOE TO INSTRUMENT PANEL CONTACT/CLEARANCE(5) RIGHT FOOT	LEFT FOOT	TOE-GUIDE CONTACT(5) RIGHT	LEFT
1	10-24-79	DUMMY	C.G.95	--	--	--	0	10	11.0	138				
2	10-25-79	DUMMY	C.G.95	--	--	--	0	10	10.6	128				
3	10-25-79	DUMMY	C.G.95	--	--	--	0	10	10.3	119				
4	10-25-79	DUMMY	C.G.95	--	--	--	0	10	10.3	127				
5	10-28-79	DUMMY	C.G.95	--	--	--	0	10	11.0	131				
6	10-29-79	DUMMY	C.G.95	--	--	--	0	10	10.8	128				
7	11-1-79	B	157	10	2	9	1.25	6	4.4	31				
8	11-1-79	E	183	25	30	9	3.2	5	4.2	32				
9	11-2-79	D	186	35	40	10	1.0	7	3.7	22				
10	11-6-79	I	151	65	30	9	2.25	7	6.0	87				
11	11-6-79	C	183	40	45	8½	3.25	7	5.7	68				
12	11-6-79	H	184	20	20	8	2.25	5	5.3	83				
13	11-8-79	I	152	65	30	9	2.25	7	7.6	97				
14	11-8-79	C	189	40	45	8½	3.25	7	7.4	86				
15	11-8-79	H	186	20	20	8	2.25	5	7.4	78				
16	11-9-79	B	158	10	2	9	1.25	6	9.2	129				
17	11-9-79	D	187	35	40	10	1.0	7	8.1	101				
18	11-9-79	E	181	25	30	9	3.2	5	8.9	98				
19	11-15-79	H	184	20	20	8	2.25	5	8.9	86				
20	11-15-79	C	189	40	45	8½	3.25	7	9.6	110				
21	11-15-79	I	152	65	30	9	2.25	7	9.8	116				
22	11-16-79	B	158	10	2	9	1.25	6	12.1	166				
23	11-16-79	E	178	25	30	9	3.2	5	11.3	133				
24	11-16-79	D	185	35	40	10	1.0	7	10.8	156				
25	11-19-79	C	179	40	45	8½	3.25	7	11.4	158				
26	11-19-79	H	186	20	20	8	2.25	5	12.1	169				
27	11-19-79	I	152	65	30	9	2.25	7	12.3	182				
28	11-20-79	B	158	10	2	9	1.25	6	13.9	215	CLEAR 1½"	CLEAR 1-5/16	YES	YES
29	11-20-79	E	178	25	30	9	3.2	5	13.2	190	CLEAR 1/16"	CLEAR 5/16"	YES	YES
30	11-20-79	D	186	35	40	10	1.0	7	12.5	195	CLEAR ½"	CLEAR 2½"	NO	NO
31	11-21-79	H	187	20	20	8	2.25	5	13.0	205	CLEAR 1/2"	CLEAR 3/4"	YES	YES
32	11-21-79	I	153	65	30	9	2.25	7	13.6	200	CONTACT 1/16"	CONTACT 1"	YES	YES
33	11-21-79	C	187	40	45	8½	1.87	8	13.3	203	CONTACT 1"	CLEAR 7/8"	NO	NO
34	11-27-79	G	242	90	98	12	0	10	6.6	82				
35	11-29-79	G	241	90	98	12	0	10	8.4	106				
36	11-29-79	D	186	35	40	10	0	9	11.1	155				
37	12-3-79	G	240	90	98	12	0	10	10.3	139				
38	12-7-79	G	241	90	98	12	0	10	11.5	159	CONTACT 7/8"	CONTACT 2"	YES	YES
01	1-10-80	E	181	25	30	9	3.2	5	13.4	204	CLEAR ½"	CONTACT 1"	YES	NOT USED
02	1-10-80	H	182	20	20	8	2.25	5	13.5	208	CLEAR 1/8"	CONTACT 2"	YES	NOT USED
03	1-10-80	G	245	90	98	12	0	10	12.8	208	CONTACT 2½"	CONTACT 2"	YES	NOT USED

(1) Percentiles in accordance with NAEC-ACEL #533
(2) Inches up from full down and establishes D.E.P. for each subject
(3) Inches forward from full aft - (full adjustment range - ten inches in one one-inch increments)
(4) See figure 1 for typical acceleration signature
(5) Data not reported considered not valid due to sub-operational accelerations

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